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A Strategic Plan for the Conservation and Restoration of Arctic Grayling in the Williston Reservoir Watershed

B. G. Blackman
June 2001

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A STRATEGIC PLAN FOR THE CONSERVATION AND RESTORATION OF ARCTIC GRAYLING IN THE WILLISTON RESERVOIR WATERSHED

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EXECUTIVE SUMMARY

Arctic grayling has a variety of characteristics, which make it extremely vulnerable to resource development (and the resulting habitat perturbations), and to overharvest by anglers.

The Michigan grayling (sub species) became extinct around 1936 because of overfishing and habitat degradation and the Montana grayling (sub species) have been extirpated from most of its former range for similar reasons.

Arctic grayling were abundant in the upper Peace, Finlay and Parsnip watersheds before the construction of the W.A.C. Bennett dam and the flooding of the reservoir in 1968.

This species remained abundant in both the reservoir and streams until the early 1980's when populations started to decline. Arctic grayling had almost completely disappeared from the reservoir by 1988 and most populations in smaller streams flowing directly into the reservoir have disappeared as well. There are still viable populations in some of the larger less accessible rivers.

It is suspected that a combination of overfishing, stream habitat degradation and the decline of productivity / suitability in the reservoir have contributed to the severe declines in Arctic grayling stocks.

Arctic grayling were classified as "red listed" (G1 QS1 / critically imperilled) within this watershed in 1995 and catch and release regulations have been in since 1996. A literature review summarising life history and habitat requirements and well as evaluating enhancement options has been completed. Preliminary surveys have been conducted in some key areas to document distribution and relative abundance and there are ongoing studies evaluating the genetic makeup of the remaining populations, habitat utilization and migratory patterns.

The purpose of this plan is to provide a co-ordinated approach to preserve and restore Arctic grayling populations and their habitat within the Williston Reservoir watershed .

Goal Statement:

" To conserve and restore wild Arctic grayling populations and their habitat through effective management strategies"

Objective 1-Develop a thorough understanding of Arctic grayling biology in British Columbia with emphasis on Williston Watershed.

To develop effective and defensible conservation and restoration strategies, reliable data on the distribution, genetics, life history, and habitat requirements of Arctic grayling is required. This information is largely lacking at this time and requires a co-ordinated effort with other agencies and resource companies to collect and store data in a usable and retrievable fashion.

Objective 2 - Develop watershed specific management strategies to conserve and restore native Arctic grayling stocks.

The present conservative regulations and habitat protection may be insufficient to stop the decline of Arctic grayling stocks. The development of long term specific strategies that will incorporate newly gathered data is required to insure the restoration of the stocks to optimum levels.

Objective 3- Protect, restore and manage Arctic grayling habitat.

Arctic grayling are a key indicator species of aquatic ecosystem health. It is vital that habitat concerns are identified and relayed to all resource management staff involved with habitat protection, as well as resource developers. Armed with results from research on habitat requirements it may be possible to restore or enhance previously perturbed sites.

Objective 4- Inform and educate the public regarding concerns for Arctic grayling stocks and involve them in conservation and restoration efforts.

Conservation and restoration strategies will fail if there is not public support. Informational / educational materials to describe Arctic grayling values, sensitivities and conservation objectives must be developed and accepted by the public. Further input must be solicited from all affected or interested parties during the management plan development process.

A STRATEGIC PLAN FOR THE CONSERVATION AND RESTORATION OF ARCTIC GRAYLING IN THE WILLISTON RESERVOIR WATERSHED

INTRODUCTION

The purpose of this report is to provide a co-ordinated approach to Arctic grayling inventory, research, management and restoration in the Williston Reservoir watershed in light of declining stocks, and rapid resource and access development. Implementation of this plan will help conserve and restore this valuable wild species. The plan presented here is consistent with the PWFWCP Fisheries Program Strategic Plan and the Provincial Conservation and Wild Indigenous Fish Policies.

Arctic grayling in the Williston Reservoir Watershed

Little is know about the numbers and distribution of Arctic grayling *(Thymallus arcticus)* in the upper Peace River watershed prior to the construction of the W.A.C. Bennett Dam in 1968 and the formation of Williston Reservoir. It is suspected that Arctic grayling were distributed throughout the watershed although anecdotal information suggests that there was limited utilization of the Finlay and Peace River mainstems because of the glacial nature of these streams. Studies conducted in 1974 & 75 found Arctic grayling were the most numerous game fish species in most streams tributary to the reservoir. Gill netting studies during the same period found grayling comprised 13% of the gamefish captured in the reservoir. A creel survey conducted in 1977 found 58% and 23% of the angler harvest from the Peace Reach and Finlay Forks area was Arctic grayling. Grayling populations were high into the early 1980's when populations crashed. Gill netting studies conducted on the reservoir in 1988 captured only two Arctic grayling. A creel survey conducted in that same year reported only 0.9 and 1.1 % of harvest from the Peace Reach and Finlay Forks area was attributable to grayling. Stream surveys conducted during the period from 1989 to 1992 on twenty six sfreams which historically had supported Arctic grayling found viable populations in only two.

There are now no viable Arctic grayling populations in any stream entering the Peace Reach (15 streams with 169 km of accessible habitat). Only two systems in the Parsnip Reach (30 streams with 969 km of accessible habitat), the Nation River and some tributaries of the upper Parsnip River still have grayling. No grayling were found or have been reported from streams entering the east side of the Finlay Reach (8 streams with 170 km of accessible habitat). There are still populations in the Omineca Osilinka Mesilinka, Finlay and Ingenika river systems

This population decline has been so dramatic that the species has been classified as G1QS1/ critically imperilled (red listed) within the Williston Reservoir watershed and catch and release regulations have been implemented.

Biology of Arctic grayling

Arctic grayling are one of the first fish to spawn in the spring, starting when water temperatures reach 4 ° C, and continuing from mid May to mid June. Arctic grayling usually spawn over clean gravel in water 30-80 cm in depth but a wide range of conditions, locations and habitat types

have been reported. In some systems the majority of fish may spawn at one location. Both sexes are highly polygamous. Males defend territories in riffles and will spawn with any female that swims into their territory, while females move about the stream, spawning with many different males. Grayling do not build redds, but the eggs are usually deposited at a depth of two to three cm in small gravel. Egg mortalities can be quite high but fecundities range from 3,000 to 14000 eggs with average fecundity of 7,000.

The fry normally hatch in about two to four weeks at a size of seven to fourteen millimetres. During the first two to three weeks after hatching, the fry are small have limited swimming abilities and require a constant and abundant food supply (e.g. chironomid larvae). After hatching, the fry tend to concentrate in dense schools in alcove habitat (shallow low velocity), immediately downstream from spawning areas. Arctic grayling can spawn in many different habitat types, but the proximity to rearing habitat for the fry may be more important than the spawning habitat itself. At this stage they are very vulnerable to flooding and mortalities can be very high either by turbulence or indirectly by starvation. It is not uncommon for entire year classes to be lost. The fry rear in very shallow low velocity areas along the stream margins usually over cobble substrate, which makes them vulnerable to stranding if water levels drop.

Arctic grayling utilize a wide variety of stream habitats from large mainstem rivers to small alpine streams. There appears to be limited use of lakes in British Columbia although utilization of lake habitats is common throughout the rest of the species distribution. This species is usually associated with clean cold waters and actively avoids turbid waters. However, Arctic grayling are tolerant of high temperatures (upper lethal temperature 25°C) and can survive winter oxygen levels of less than 1 ppm.

Arctic grayling exhibit a wide variety of life history patterns and are renowned for long migrations between overwinter, spawning and summer feeding areas. There appears to be a high fidelity to return to the same areas each year and some studies have found several distinct genetic stocks within a single river, There appears to be little genetic exchange between these stocks despite the fact the adults all utilize the same summer feeding area.

Grayling tend to exhibit a similar distribution pattern in many systems with the largest adults occupying the upper reaches of the stream, sub adults in the mid reaches and younger age classes in the lower reaches. Young of the year are most frequently found in the mainstem, but tributaries, mainstem side and back channels are also utilised. Preliminary information suggests the one year old grayling may drop downstream out of smaller systems to rear in larger mainstem habitats.

Arctic grayling become sexually mature when they reach a fork length of approximately 30 cm, or at four or five years of age, although longer lived northern stocks may mature slightly later. Stocks in the Williston Reservoir Watershed normally live for six to eight years.

Possible Reasons for the Decline of Arctic grayling

Overfishing is suspected of being one of the primary causes of the decline of grayling in this watershed. There are numerous references in the literature to the extreme vulnerability of Arctic grayling to overfishing. Bruce and Starr in their 1985 report on Williston Reservoir tributaries cited non compliance with regulations as a problem in this drainage. Anecdotal information from local anglers indicates there were tremendous catches" pick up truck loads" at the stream mouths in spring after the reservoir was flooded. The nearly complete disappearance of Arctic grayling

from Carbon Creek occurred only four years after road access was developed and this decline was attributed to overfishing.

Habitat degradation was also a contributing factor in the decline of grayling populations. The formation of the reservoir flooded large areas of mainstem habitat as well as the lower reaches of most tributary streams. However, populations did not start to decline until ten to twelve years after the reservoir was flooded. In the early stages of the reservoir, floating log mats and elevated nutrient levels resulted in excellent habitat providing both cover and food. (According to local residents insect production from the floating log mats was very high.) The log debris also restricted angler access to many areas. The population decline most closely coincides with the clearance of debris from the reservoir in the early 1980's.

The reservoir now provides less suitable habitat, the debris mats are gone, nutrient levels have dropped, angler access to the stream mouth areas is good and the water regime or the reservoir with its 20 meter drawdown severely limits littoral production. Preliminary data suggests that one year old Arctic grayling may drop downstream to rear in large mainstem habitat. This habitat has been replaced by the reservoir in all but the largest systems, which still support viable populations. This age class may not be able to compete in the reservoir environment. The reservoir provides suitable habitat for some species, which may now have a competifive advantage over grayling.

The reservoir may also affect migrations to and from overwintering areas. In winter the reservoir may work like a heat and food sink, which results in high concentrations of fish near the dam site. Historically large numbers of grayling followed the temperature and food to the area of the dam where they could have been lost through entrainment or at a minimum had greater distances to return to spawning streams.

Industrial activities such as mining or logging resulted in increased silt loads and large clear cuts can lead to a faster spring snow melt higher spring floods and lower late summer flows. Some studies suggest that grayling may be more tolerant of fines in the spawning substrate than other salmonids but they are less tolerant for feeding and rearing purposes. The most vulnerable period for Arctic grayling is the first two to three weeks after hatching. During this period flood events can eliminate an entire year class. Any physical loss of the key early rearing areas (shallow low gradient areas downstream from spawning grounds) could severely reduce production from a stream and reduced late summer flows can result in sever losses due to stranding.

Beaver dams can also be a serious problem, particularly in small low gradient streams. The dams may block fish passage, trap fish and raise water temperatures. Higher water temperatures (>15-20°C) are tolerated by grayling but may give competing species an advantage.

One single factor alone would probably not have resulted in the extirpation of the grayling stock(s) but the combination of severe over fishing, habitat degradation in spawning and early rearing areas, and a less that suitable reservoir habitat, which could give competing species an advantage, has tipped the scale in much of this watershed.

GOAL STATEMENT:

To conserve and restore wild Arctic grayling populations and their habitat through effective management strategies.

STRATEGIC OBJECTIVES:

OBJECTIVE 1 - Develop a thorough understanding of Arctic grayling biology in British Columbia.

Strategy 1.1 Establish data collection and inventory standards for Arctic grayling research.

Activities:

a) Develop a five year plan which identifies and prioritises information needs, and how the information will be used to better manage this species;
b) Establish standardised methodologies for data collection, and reporting
c) Develop standardised methodologies, to determine age class distribution, population density, non -obtrusive techniques to mark fry, and adults, and validate and standardise ageing techniques;
d) Establish communications to exchange information with other researchers in the field, conduct literature reviews and organise or participate in workshops to discuss mutual problems, findings and methodologies.

Strategy 1.2 Investigate the zoogeography and population genetics of Arctic grayling in B.C.

Activities:

a) Determine present distribution of Arctic grayling populations by conducting overview inventories;
b) Supplement historic data on distribution using local knowledge;
c) Create suitable GIS layers for the Watershed atlas that will permit historic and present distributions to be displayed;
d) Define genetic structure using physical habitat structure and molecular biological techniques;
e) Define evolutionary Significant Units as groups of genetically isolated populations that share a suite of adoptively significant characteristics;
f) Develop restoration and protection strategies based on sound genetic data.

Strategy 1.3 - Investigate Arctic grayling life history and habitat requirements using index streams.

Activities:

a) Establish criteria and catalogue index streams for Arctic grayling research that includes a broad range of the geographic variation and alternative life history strategies found in Williston Reservoir watershed;

b) Investigate habitat needs, limitations and capability by examining micro-habitat distribution of each life history stage;
c) Determine what habitat characteristics are most important for determining spawning and early rearing areas, what factors will most dramatically affect spawning success and what habitat improvements can be used to increase survival rates;
d) Determine the affects of flow regime and siltation, industrial activities and restoration projects on the different life history stages, and initiate a monitoring program that will evaluate the long term effects on grayling populations;
e) Determine traits such as growth rates, length at age, age at maturity, fecundity / size relationships for all populations;
f) Determine timing and location of key life history events especially spawning, summer feeding, overwinter and migration routes for all remaining populations;
g) Determine if homing to spawning areas is learned or genetic or a combination;
h) Determine if migration patterns are learned, genetic random or related to water conditions;
i) Determine factors limiting production at each life history stage.
j) Develop index methods to determine changes in populations at the different life history stages (i.e. egg to fry survivals, over summer survival growth of young of the year, age class strengths, etc);
k) Determine contribution of young of the year fry that are displaced by high flow events or trapped in isolated pools by low flow events;
l) Investigate infra- and interspecific competitive relationships.

OBJECTIVE 2 - Develop watershed specific management strategies to conserve and restore native Arctic grayling stocks.

Strategy 2.1 Institute conservative angling regulations to protect Arctic grayling from over harvest.

Activities:

a) Maintain catch and release regulations in areas where this is in effect;
b) Encourage compliance through signage and public educational projects;
c) Use results of index system studies to modify regulations as results become available;
d) Communicate management concerns and strategies to other agencies to minimise the possibility of conflicts;
e) Communicate / educate and encourage input from enforcement personnel.

Strategy 2.2 Develop protected genetic reserves for the remaining stocks (these stocks may provide a source for transplants for future reintroduction's).

Activities:

a) Identify and evaluate suitable locations to establish genetic reserve populations;
b) Use pilot projects to determine which methods are most effective for establishing genetic reserve populations;
c) Identify a source of fry/eggs (radio telemetry identification of key spawning areas) and adults for these transplants;
d) Develop methods for capturing and transporting fry and eggs.

e) Create genetic reserves for all unique stocks;
f) Insure these reserves are protected from impacts through integration of access, land use and higher level planning.

Strategy 2.3 Reintroduce Arctic grayling back into historical systems

Activities:

a) Using previous studies and anecdotal information determine which systems supported large numbers of grayling;
b) Evaluate potential reintroduction sites taking into account, habitat impacts that have occurred, possible habitat limitations, interspecific competition, compatibility between donor source stream and recipient stream characteristics:
c) Evaluate the genetic implications of reintroducing specific genetic stocks into historical streams;
d) Develop sources of fry or eggs to use as transplant donor sources including suitable methodologies for capturing and transporting;
e) Conduct habitat improvement / restoration projects that will increase the probability of successful reintroduction's;
f) Insure no potential resource use conflicts through planning, co-operation with industry and public involvement;
g) Initiate pilot projects to re-introduce grayling back into historical streams.

OBJECTIVE 3- Protect, restore and manage Arctic grayling habitat.

Strategy 3.1 Identify Arctic grayling habitat protection concerns and make information available to all resource management staff involved with habitat protection issues and planning.

Activities:

a) Use research on habitat requirements to identify key habitat protecfion concerns;
b) Develop index systems to evaluate the effectiveness of present habitat protection criteria in preserving Arctic grayling populations;
c) Provide briefing materials regarding Arctic grayling habitat protection objectives;
d) Identify the locations of specific critical or sensitive habitats;
e) Use planning as a tool to protect and maintain no-access refugia;
f) Assist in guidelines development to ensure Arctic grayling needs are addressed in stream and riparian protection schemes;
g) Design projects to evaluate the effects of land use, habitat protection and restoration work on Arctic grayling populations.

Strategy 3.2 Develop Habitat Enhancement projects to restore or improve Arctic grayling production capability.

Activities:

a) Use research on habitat requirements to identify limiting factors affecting Arctic grayling production;

b) Using historical range and known impacts in areas where Arctic grayling have been extirpated, assess or deduce the habitat changes that have occurred that may have contributed to extinction;
c) Conduct pilot projects to determine the effectiveness of various habitat improvement options for Arctic grayling;
d) Seek project funding through initiatives such as Forest Renewal B.C. and encourage interaction on projects with other resource agencies and industry.
e) Develop index streams to determine the effectiveness of habitat restoration on Arctic grayling populations;
f) Develop methodologies to document changes in Arctic grayling populations as a result of habitat degradation or restoration;
g) Monitor changes in sediment transport with respect to industrial activities and restoration projects;
h) Create or improve backwater or backchannel habitat in key rearing areas and document use, survival and growth rates in comparison to unimproved areas.

OBJECTIVE 4 **Inform and educate the public regarding concerns for Arctic grayling stocks and involve them in conservation and restoration efforts.**

Strategy 4.1 **Develop informational / educational materials describing Arctic grayling values, sensitivities and Program objectives.**

Activities:

a) Develop take home materials such as posters and pamphlets;
b) Develop presentation materials, such as slide shows or videos that can be used in stand alone displays or as part of a presentation to schools, clubs etc;
c) Develop a plan to deliver and disseminate informational materials;
d) Insure areas with Arctic grayling populations where there is angler access are signed with regulations and information is provided to explain the rationale behind these regulations.

Strategy 4.2 - **Solicit input and support from First Nations and the public in the development of management plans.**

Activities:

a) Conduct surveys of anglers and other interested parties to determine the level of awareness, motivations, use statistics and preferred management options;
b) Hold workshops with key groups to provide background information, solicit input and obtain support for new conservation strategies.
c) Involve the public, interest groups, First Nations and local industry whenever possible

Work Plan and Time Lines

ACTIVITY / INVESTIGATION (strategy activity)	RATIONAL / USE	METHOD	TIME
DEVELOPAN UNDERSTANDING OF GRAYLING BIOLOGY			
Data Collection and Inventory Standards			
Develop 5 yr. Plan Identifying Critical Data Needs (1.1 a)	- provide better direction and organisation to the program - provide specific goals and timelines,	-develop a management plan, five year plan and yearly work plan.	March 31,01
Standardise methods and reporting (1.1 b)	-grayling populations have rather unique life history patterns which makes many standard methodologies unsuitable.	-test different assessment methods, review literature, information from other grayling researchers	1997-
Develop methods to determine age class composition population density (1.1 c)	- grayling distribution and migration patterns make standard survey techniques unsuitable.	-test different assessment methods and review literature talk to other grayling researchers	1996-
Methods for marking (1.1 c)	- need to mark and track large numbers of individual fish in a non obtrusive manner. (Floy tags cause problems and are not suitable for smaller fish).	- test the use of pit tags and investigate methods for marking young of the year fry. -literature review	1998-
Methods for ageing (1.1 c)	-are some problems with using scales to age older fish, fin rays appear to give slightly better results but are much more expensive and long term effects (infection fungal attacks or increased predation) need to be evaluated,	-initiate a multi year project evaluating the survival rates of fish that have had fin ray samples taken and fish that have only been scale sampled.	1997-2000
Communications with other researchers (1.1 d)	- good communications and co-operation with other researchers in this field is essential.	-continued literature reviews, develop a communication link with others in the field (E.Mail) organise / attend workshops to discuss findings and common problems.	1994-1999
Investigate Zoogeography and Population Genetics			
Determine present and historical distribution (1.2 a, b)	- historical distribution/present distribution...what was suitable habitat and to help determine why they have disappeared.	-valuation of historical evidence and past and ongoing inventory programs (ours and other agencies). Need information on upper Parsnip, Pack, Finlay, Ingenika, Omenica and Osilinka Systems.	1988-ongoing
Assess local knowledge (1.2 b)	-gather invaluable local knowledge	-surveys and interviews have been conducted and will be continued.	1988-
Create GIS Data Base (1.2 c)	- data has been incorporated in the FIS data base	-new information will be added to the GIS data base	1995-
Define Genetic Structure (1.2 d)	-determine genetic basis of populations, source of populations, degree of uniqueness and exchange of genetic information between populations, -essential to determine management approach and information needs.	- are in the third year of a three year program of genetic evaluations, -program needs to be ongoing / expanded to cover other areas of the watershed, -require methods to gather, integrate and evaluate future data,	1996-
Identify significant genetic populations (1.2e)	-determine if there are many unique stocks or a common stock, -evaluate the differences between stocks -management implications	-genetic sampling program	1996-2001

ACTIVITY / INVESTIGATION (strategy activity)	RATIONAL / USE	METHOD	TIME
Develop Restoration and Protective strategies based on sound genetic information. (1.2 f)	- essential that all unique stocks are preserved and that restoration work will maintain or increase genetic diversity.	-sound analysis of genetic data and implementation of projects that will protect the genetic diversity of the stocks.	2002-
Investigate Life History and Habitat Requirements Using Index Streams			
Establish broad range of index streams (1.3 a)	-if there are genetic differences between stocks it will presumably be between systems with differing characteristics.		1999-2003
Establish index criteria and catalogue (1.3 a)	- determine what factors (drainage area, flow regime, temperature, gradient, species composition, etc) affect life history strategies and possibly genetic makeup of populations	-use genetic data and compare with inventory information. Prime factors to consider, flow regime (timing and duration of spring freshet) , water temperature, species composition, stream morphology etc	
Investigate habitat needs, limitations and capabilities for all life history stages (1.3 b)	-in order to protect or restore habitat it is essential the we understand habitat use for all life history stages -habitat limitations and capabilities are required to determine factors that may limit or restrict populations at certain life history stages.	-evaluate habitat availability / use/ preference for different life history stages. In the Table and Anzac Rivers adult use appears to be primarily influenced by feeding stations habitat utilization is primarily pools or glides. Fry utilization is controlled by velocity, depth then substrate, juvenile (1 +) habitat preference has not been determined. Adult overwinter preferences are highly variable.	1996-
Determine most important habitat characteristics for spawning and potential restoration (1.3 c)	-it will be difficult to locate all spawning areas so characterising known areas will be important for habitat protection/ restoration works, -selection of spawning areas immediately upstream of suitable early rearing habitat and in areas that minimise impacts of flooding appears to be a key element.	-radio telemetry projects are essential to locate spawning areas. To date all known spawning have been located in areas with small clean gravel substrate and primarily in multi channelled areas or in two instances tributary streams.	1997-
Habitat characteristics effects on early survival and potential restoration (1.3 c)	- will probably be a / the key factor in habitat protection / restoration that we can directly influence.	-evaluate habitat use and survival rates of different areas under different flow regimes. - identify areas, develop marking and capture methods and methodologies to evaluate projects	1997-
Effects of flow, siltation industrial activities and restoration projects on life history stages (1.3 d)	-our studies and the literature suggests that flow rates during spawning and early rearing directly influence recruitment; turbidity affects growth, survival and distribution; low summer flows can strand a high percentage of fry resulting in high mortalities. - need to determine what habitat characteristics or restoration projects would minimise these impacts,	-devise methodologies and set up long term monitoring projects to measure population changes with respect to flow and siltation etc. -determine how site or macro populations are affected i.e. how habitat selection can moderate or buffer negative environmental impacts,	1997-
Monitor long term affects of flow, siltation rates, industrial activities and restoration projects on populations (1.3 d)	-effects of industrial activities and restoration projects may not have immediately measurable impacts on populations so it is important to develop long term monitoring projects	- important to develop an inexpensive, replicable and reliable monitoring program that evaluates the affects of a large number of factors over a large area and single variables at specific sites.	1997-

ACTIVITY / INVESTIGATION (strategy activity)	RATIONAL / USE	METHOD	TIME
Growth rates, length at age, age at maturity, fecundity / size relationships (1.3 d)	- standard population parameters that need to be determined and comparisons made among watershed populations and between other populations that have been studied elsewhere.	-standard methods literature reviews and information from other researchers - evaluate growth vs. survival data.	1994-
Tinning and locations of spawning areas (1.3 f)	- essential to locate as many specific spawning areas for habitat protection, (fisheries sensitive zones or designation as special wildlife management areas) and to allow comparisons to be made to determine to range of habitat requirements (use) under different flow and temperature regimes.	radio telemetry studies and follow up ground based surveys on selected sites.	1996-
Migrations patterns of different populations (1.3 f)	- evaluate migration patterns within and between populations to help protect and manage individual populations.	radio telemetry studies	1996-
Homing to spawning areas learned or genetic (1.3 g)	- will strongly influence the methods used and success of reintroduction's	Difficult- genetic and fry marking studies	1999-
Migrations, learned, genetic or environmental (1.3 h)	- the methods used and success of reintroduction's - choice of stock(s) for re-introductions	Genetic and long term marking projects	1996-
Factors limiting production (1.3i)	-determine what factors most strongly limit populations under given circumstances (may not always be the same factor) so that efforts can be directed towards factors that will have the greatest positive benefit.	Develop methods and initiate studies to evaluate: -egg to fry survival rates under different conditions; -early rearing survival rates under differing conditions; survival to age 1 + etc.	1998-
Index methods for population changes (stage) (1.3 j)	-determine changes in different populations to evaluate the effectiveness of different management prescriptions	-adult population estimates, fry densities, growth rates, survival rates, population structure, etc.	1995-
Contributions of young of the year (yoy) displace or in isolated pools (1.3 k)	-the contributions of newly hatched fry that are or are not displaced by high flow and contributions of fry utilizing isolated pools along the stream margins will strongly influence management and habitat protection / restoration approaches.	-develop fry marking and capture techniques and design a five year marking and monitoring program.	1998-
Inter and intraspecific competition (1.3 l)	- Arctic grayling populations may not compete well or be compatible with rainbow trout. If this is the case it will strongly influence the choice of streams where reintroduction's will be conducted.	-compare habitat use, growth and survival of sympatric and allopatric populations particularly in warm and coldsystems.	1996-
DEVELOP WATER SPECIFIC STRATEGIES TO CONSERVE AND RESTORE			
	Conservative Regulations		
Catch and Release (2.1 a)	-catch and release regulations have been imposed throughout the watershed.	-to insure compliance with the regulations, signs should be placed at key access points and a public education program should be initiated .	1995
Modify regulations (2.1 c)	-if populations respond well to the catch and release regulations some selected areas could be opened to a limited harvest.	-thorough evaluations of populations will be necessary prior to and during any harvest.	
Communications with other agencies (2.1 d)	-insure that other agencies are made aware of critical issues and activities to reduce the possibility of resource use conflicts.	-development of briefing notes, pamphlets and incorporation of strategies into land use plans	1997

ACTIVITY / INVESTIGATION (strategy activity)	RATIONAL / USE	METHOD	TIME
Genetic Reserves			
identify suitable locations (2.2 a)	-identify suitable habitats (small barren or monoculture lakes with no rainbow trout) that stocks can be transplanted to and allowed to establish without potential negative impacts.	-some lakes have been identified through reviews of existing inventories, through PWFWCP inventories and through FRBC funded inventories. FRBC and Forest industry directed inventories may identify additional lakes but these will probably be in areas with potential forest harvest impacts.	1992-
Pilot projects methods (2.2 b)	-a previous transplant into an open system using adults appears to have been unsuccessful and expensive, -use of fry, eggs or gravid adults should be tested, -interspacific competition primarily rainbow trout also needs to be evaluated.	-more cost effective adult capture methods should be investigated and efficient methods to capture fry need to be devised -develop criteria to evaluate potential reserve stock locations	1997-
Source fry/ eggs / adults (2.2 c)	-potential donor sources will be necessary to establish genetic reserve populations and possibly for reintroduction's to historical streams	- telemetry program will provide locations of key spawning and adult holding areas in the various systems.	1996-
Methods for capture and transport (2.2 d)	-the capture of adults has been a time consuming and costly project and to date the capture of significant numbers of fry or gathering eggs has been impossible. More efficient methods and locations for this activity are needed to make future projects economically feasible.	-as part of the monitoring program methods to capture prespawning adults and newly hatched fry will be tested.	1997-
Genetic reserve for each stock (2.2 e)	-develop a separate genetic reserve for each unique genetic stock to protect all stocks and allow for the use of a diverse gene pool for reintroduction's	-the genetic sampling program will show how many unique genetic stocks are present. Some additional work may be necessary for more remote stocks and stocks which have not been sampled sufficiently.	1996-
Protect reserves (2.2 f)	- insure that no habitat degradation takes place that could affect the genetic reserve populations. Access development to these areas will also have to be controlled,	-information on these critical areas will have to be incorporated into the land use planning process or agreements made with local industry.	1992-
Reintroduce back into Historical streams			
Determine which systems supported grayling (2.3 a)	-historical distribution information has been evaluated but criteria and evaluations will have to be developed to insure success.	-continue to review historical records and local information sources.	1988-
Evaluate changes to the systems (2.3b)	-habitat degradation impacts may still reduce the capacity of some systems.	Stream inventory and video surveys,	1988-
Determine habitat limitations / interspacific competition (2.3b)	-insure habitat is suitable for Arctic grayling and that potential competing species are not going reduce the likelihood of success.	-habitat and species distribution surveys	1998-
Compatibility of donor source (2.3 c)	-Arctic grayling have a tendency to be specialists to more efficiently utilize a specific resource. This can result in populations with limited genetic diversity and an inability to adapt to new environments.	-transplant sources should come from physically similar systems to insure compatibility or from several diverse sources to provide genetic diversity which will allow a new genetic stock to develop that would be suitable to the new environment.	1997-

ACTIVITY / INVESTIGATION (strategy activity)	RATIONAL/USE	METHOD	TIME
Evaluate potential resource conflicts (2.3 f)	-limit negative environmental impacts until the stocks are well established.	-integrate program with local resource use plans and insure all agencies and possible resource users are aware of and in support of the projects.	1998
Initiate and evaluate pilot projects (2.3 g)	-there are a great many variables that may be impossible to account for. Good planning and background information will go along way to insuring the success of projects but never the less some failures may occur.	-reintroduction techniques should be thoroughly evaluated to determine the reasons for success and failures, -evaluate thoroughly what has been done in other areas.	2001
PROTECT RESTORE AND MANAGE HABITAT			
Identify habitat protection concerns and make information available			
Identify key habitat protection concerns (3.1 a)	-to prevent further declines in stocks it will be necessary to determine what factors are most critical and insure these areas receive the maximum protection possible.	-locate critical habitat areas (telemetry) and evaluate vulnerability to habitat degradation.	1996-
Produce and provide briefing materials (3.1 c)	-provide information to both habitat protection staff and user groups	- conducted as part of public consultation	1998-
Identify specific critical areas (3.1 d)	-to provide additional habitat protection it is critical to identify these areas and determine what additional protective measures are necessary,	Locate specific spawning and early rearing areas and identify them as Wildlife Management areas with the associated additional habitat protection.	1998-
Protect refugia areas through land use planning (3.1 e)	-minimise negative habitat impacts in key areas	-special area designations	1992-
Assist in guideline development (3.1f)	-protection of Arctic grayling habitat will require special guidelines and incorporation into the Forest Practises Code,	-inventory and monitoring programs will provide information on the effectiveness of the present guidelines and point out where more care is needed.	1999-
Evaluate effectiveness of protection and restoration on grayling populations (3.1 g)	-critical to determine if the present habitat protection guidelines are adequate. It is also advisable to determine which habitat restoration techniques have the greatest benefit for grayling populations.	-inventory and monitoring programs will provide information on the effectiveness of habitat protection guidelines and benefits of habitat restoration work. -will require a long term monitoring program that examines site and system population responses.	1999-
Habitat Enhancement Projects			
Research to determine habitat limitations (3.2 a)	-to determine what types of habitat enhancement / restoration projects would be most effective in restoring system capabilities	-see life history and habitat requirement	1998-
Assess past habitat impacts (3.2 b)	-outside funding (FRBC) may be available to restore habitats that have been impacted by logging.	-stream inventory, air photo interpretation and stream video's.	1988-
Initiate and evaluate habitat improvement projects / index streams (3.2 c,e)	habitat improvement projects should increase the capability of streams and increase survival rates. Priority would be given to systems with exiting stocks that have been impacted,	- standard habitat improvement / restoration techniques will be used that will specifically benefit grayling. All projects will be evaluated.	1996-
Seek outside funding (3.2 d)	- a great deal of the impacts are a direct result of timber harvesting and funding should be available for restoration projects through FRBC.	-funding can be applied for directly to FRBC or through joint submissions with the forest companies or other interested parties,	1996-

ACTIVITY / INVESTIGATION (strategy activity)	RATIONAL / USE	METHOD	TIME
Develop methodologies to evaluate population changes with respect to habitat changes (3.2 f)	-subtle changes in grayling populations may be masked by other environmental variables. Methods will have to be developed that will detect small changes or account for environmental variables.	-use sound biological methods, develop control/ index sites and compare results with other researchers	1998-
Monitor sedimentation rates with respect to restoration / industrial impacts (3.2 g)	-determine effects of changes in sedimentation rates caused by industrial activities and restoration projects. Determine if present guidelines are adequate and if restoration projects are beneficial,	-set up long term monitoring stations in co-operation with Environmental Protection	1998-
Create backwater / channel habitat and evaluate (3.2 h)	- information available suggests backwater and groundwater fed side channels will probably be the areas least affected by flooding increased silt loads and low summer flows.	-develop or improve these habitats and monitor utilization and survival rates in comparison to control areas.	2002
INFORM, EDUCATE AND INVOLVE THE PUBLIC IN CONSERVATION AND RESTORATION EFFORTS			
Informational / Educational materials			
Take home posters and pamphlets (4.1 a)	-educate the public, gather support and increase compliance with regulations,	-in co-operation with PWFWCP Public Consultation Program	1998-
Presentation, slide shows and video's for presentations or stand alone displays (4.1 b)	-educate the public, gather support and increase compliance with regulations,	- as part of the Public Consultation Program	1998-
Informational delivery Plan (4.1 c)	-improve efficiency of delivery and insure Program Objectives are met.	-incorporate into Public Consultation Plan	1999-
Signage in key areas throughout the watershed (4.1 d)	-improve public knowledge and increase compliance with the regulations.	-incorporate into Public Consultation and field activities	1996-
Solicit input from First Nations Public Interest groups			
Surveys to determine awareness, motivations preferences (4.2 a)	-provide public input and support	-Public Consultation Program, plan and biologists.	1992-
Workshops for dissemination of information, solicit input and support (4.2 b)	-provide public input, support and educate the public	Public Consultation Program, plan and biologists	1992-
Involve groups in Projects (4.2 c)	-provide public input, support, educate the public and	Public Consultation Program, plan and biologists	

INFORMATION NEEDS

INFORMATION REQUIRED	WHY	HOW WILL IT BE USED	TIME FRAME
IDENTIFY CRITICAL DATA NEEDS	Work must be directed towards attainable goals that will move towards program objectives	five year plan	1999-
establish communications to exchange information with other researchers in this field	to reduce work load and use co-operative approach	workshops, email literature reviews	2000-
DEVELOP INDEX STREAMS APPROACH	reduce work load and speed up information gathering	index streams based on hydrological regimes temperature and habitat characteristics	1999-
SPAWNING HABITAT CHARACTERISTICS			
depth velocity substrate % fines, timing temperature	habitat protection, site suitability via air photo's or inventory data (reintroduction's) habitat improvements	from literature, other researchers and in conjunction with telemetry surveys	ongoing ...three years
site selection w.r.t stream flow character	index systems , reintroduction's	classifying stream flow characteristics./ hydrological studies	classification 2 yr.
locations of key spawning areas for remaining stocks	habitat protection, planning, fry/egg source for genetic reserves/re introductions, sp habitat characteristics locations for spawning success evaluations	telemetry and index systems based on hydrological regimes	5 yr, telemetry project
FACTORS THAT AFFECT SPAWNING SUCCESS			
flow regime, sedimentation, substrate, site selection, predation	habitat protection, planning, habitat improvement projects re introductions, sp habitat characteristics	? index sites, emergence traps, literature, other researchers, hydrological studies, sediment studies, substrate evaluations, downstream traps .... will be very difficult	5 yr.
EARLY REARING HABITAT			
dispersal mechanisms	possibly single biggest factor in determining year class strength	downstream trapping and marking techniques index for spawning success	1997-
importance of lateral alcove habitat quantity, quality, distribution	key to early rearing and survival, habitat protection, habitat improvement, reintroduction's	downstream trapping, beach seines, visual observations, possibly electrofishing, marking techniques, detailed mapping	1997-
determine factors that affect growth and survival rates...density, territory size, habitat selection, temperature, flow regime, sedimentation rates, food supply, competition and predation	determine methods to improve growth and survival rates or reduce affects of negative factors	long term macro habitat evaluations coupled with flow, sediment and invertebrate studies	1997-
habitat selection of different age classes	habitat protection, habitat improvement projects, reintroduction's	habitat use/availability studies., snorkel surveys, electrofishing (backpack and boat), beach seines habitat surveys	1995-2002

AGE AND GROWTH			
validate and standardise ageing /backcalculation methods	determine affects of stream flows and temperature on growth and possibly survival rates	scale and fin ray samples, scale backcalculation work, marking techniques (fish, scales, otoliths alizarin complexone), compare year class strengths to growth/temperature/flow data... temperature and flow monitoring.	1995-1998
MIGRATION AND HOMING			
migrations to overwinter, spawning and feeding areas	habitat protection, stock monitoring, possible capture and study locations	radio telemetry	1996-
return to spawning areas... is homing to spawning areas genetic, learned or a combination??	reintroductions, utilisation of habitat improvement sites,	fry marking techniques, genetic analysis of fish from specific spawning locations.	
Stock partitioning... genetic differences between/among stocks	management of stocks habitat protection reintroduction's genetic reserves habitat improvement projects	genetic sampling studies... possibly meristic physiological and behavioural studies as well.	
GENETIC RESERVE POPULATIONS			
evaluate genetic stock partitioning	determine the number and nature of genetic reserves that will be required	genetic sampling studies	
possible sites for establishment of genetic reserve populations	establish reserves before more stocks disappear	standard inventory methods	
develop techniques for establishing genetic reserve populations	to insure success of projects/ suitability of transplant sites/ capture and transport methods	pilot projects fry/eggs into barren/open systems/ adult transplants into closed systems	